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ABSTRACT

This exploratory study examined how middle-level students preferred to work on science and science-related problems. Assessing students' instructional preferences may be as important as determining their abilities before decisions about optimal forms of education can be made. Students' preferences may indicate the types of instruction most likely to improve or maintain academic motivation and give special insight into what would be generally effective instruction. Approximately 850 middle-level students (grades 7 through 9) from 13 urban, suburban, and rural schools in 9 New York State counties were surveyed. Questions on 15 problem areas in science were distributed across 5 survey forms. Each student was asked questions on three of the problem areas and an open-ended question about what they would most like to work on in science classes. Results show that middle-level students most preferred designing solutions to a problem as opposed to deciding what to do about it or finding reasons why it was a problem. Gender, race, and community type did not generally seem to make any difference. Nearly 80% of the students who suggested ideas for learning in science classes wanted more labs and experiments. Preference research can inform the study and practice of instructional design and the means by which preferences might influence student performance. Four data tables and 10 graphs are included. (Author/TJH)

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# Students' Preferences of Types of Problems Used in Science Education

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ABSTRACT

This exploratory study examined how middle-level students preferred to work on science and science-related problems. It may be as important to assess students' instructional preferences as their abilities before deciding on optimal forms of education. Students' preferences may indicate the types of instruction most likely to improve or maintain academic motivation if not also give special insight into what would be generally effective instruction.

Approximately 850 middle-level students (grades 7-9) from 13 urban, suburban, and rural schools in 9 New York State counties were surveyed. Questions on fifteen problem areas in science were distributed across five survey forms. Each student was asked questions on three of the problem areas and an open-ended question about what they would most like to work on in science class.

Results showed that middle-level students most preferred designing solutions to a problem as opposed to deciding what to do about it or finding reasons why it was a problem. Gender, race and community type did not generally seem to make any difference. Nearly eighty percent of the students who suggested ideas for learning in science classes wanted more labs and experiments.

The paper ends with a discussion of how preference research can inform the study and practice of instructional design and how such preferences might influence student performance.

## INTRODUCTION

Throughout much of this century the central goal of education has been to make people better thinkers and problem solvers (Gagne, 1980). Efforts to accomplish this include logic-based modern math, the inquiry method of science instruction, the discovery approach, questioning at "high" cognitive levels, and emphasizing creativity. In the last decade or so there has been a movement toward scientific and environmental literacy (NSTA, 1982 and UNESCO, 1978). We continue to search for instructional designs that develop better problem solving ability, abilities to discover relationships, logical reasoning, and the ability to work toward solving current problems and prevent new ones.

Middle-level students "often have limited attention spans and are concerned with matters other than academic (Cawelti, 1988, p. 8)." A variety of options and approaches in their curriculum at this time is crucial to helping them become more self-reliant learners. Furthermore, "it is possible that differences in performance in specific courses depend principally on interests, motivation, and emotional factors (Anastasi, 1988, p. 395)."

Rita Richey (1986) wrote that instructional designers determine how to deliver instruction so that it matches learner characteristics, resources, objectives, goals, needs, and political influences. She also suggests that instructional designers use client input when creating a blueprint for delivery. Who are the clients? Students? If so, then preference research can inform instructional design.

In May of 1990, an exploratory study was conducted to determine what science and science related problems middle-level students were interested in working on in their science classes. Its primary purpose was to provide information to the decision makers who determine what will be incorporated in the New York State science syllabus and syllabus supplements.

Specifically, it attempted to determine what problem areas middle-level students were interested in learning about in their science classes. Since the results would be used to inform state-wide curriculum development it was necessary to address a variety of questions and issues. For example, are there differences in interest among the science related problem areas that correlate with gender, race, or type of community? Are there certain approaches to learning that are likely to maintain student interest and engagement in a learning activity for four to five weeks? This paper will touch on what the students indicated were their

preferences for subject matter then focus on there stated preference for ways of learning.

## METHODS

A representative sample, totaling 851 seventh, eighth, and ninth grade students, was surveyed. They came from thirteen urban, suburban, and rural schools in nine counties in New York State. Male and female students were equally represented. Furthermore, Asian, Black, Hispanic, Native American, and White were all included. Finally, students were evenly distributed across all five forms of the survey. Table 1 summarizes the demographic distribution of the students who responded to the survey.

The survey was composed of questions about fifteen problem areas in science. Ideas for these problem areas and their subtopics were gleaned from conversations with middle-level students, Associates at the Bureau of Science Education (New York State Education Department), the New York Power Pool, Rodger Bybee's (1987) national survey of science educators, and "Teaching Science-Related Social Issues" (1982). Selected items were divided into groups of three different problem areas on each of five different forms. Each student, therefore, responded to several questions concerning only three of the problem areas. All five forms contained a question concerning the scope of problems they preferred and an open-ended item soliciting their ideas about what was most interesting to learn about in science class.

The first item, in each set of three questions, provided three topics within that one problem area. Students were asked to select the one topic that interested them most or indicate non-interest in the choices available. The second item requested them to identify a preference for one of three ways of learning. Everyone had the same choices; A) "finding reasons why this is a problem," B) "deciding what to do about the problem," and C) "designing a solution for the problem." The last item asked them to rate their interest in the problem area, as a whole, on a five point Likert-type scale.

One question was present on all five forms of the survey. It asked whether local, regional, national, or world wide problems were more interesting to work on in science class. Finally, every questionnaire finished with an open-ended invitation to students to write their idea of what problem they would like to work on. An example of the types of items asked on the questionnaire may be found in Table 2.

## RESULTS

Of primary interest to the study was the intensity of interest that middle-level students had in the fifteen problem areas provided. The curriculum writers needed this information in order to select the most appropriate themes for their units. Students indicated their interest in the general problem area on a five point likert-type scale. The sum of the responses to the high and very high choices was taken as a measure of interest in each problem area and were ranked in order from highest to lowest interest. Table 3 summarizes student interest ratings for these problem areas. The most highly preferred problem areas included wildlife, water resources, and natural disasters while the least preferred areas were energy conservation, human population, and solid waste.

Every problem area offered an opportunity to ask students how they wanted to learn; i.e., finding reasons, deciding what to do, or designing solutions (see Table 2). By averaging the percentage of response to each "way of learning" across all fifteen problem areas one can see, in Figure 1, that designing solutions was most highly preferred.

When the percentage of responses to each of these choices is plotted against the problem areas, as in Figure 2, it may be seen that "designing solutions" is preferred in 14 of the 15 problem areas. Furthermore, ten of them are significant ($p < 0.05$) plus two more are substantially different ($p < 0.10$) from "deciding what to do."

There is a peculiar pattern seen in figure 2. More problems show significant results at the lower end of the interest scale than at the higher end. While less intense, a similar pattern exists with the "deciding what to do" response. A strikingly similar pattern emerged from a cross-tabulation with community type. That is, both urban and suburban students preferred designing solutions (Figures 3a and 3b). However, there was more of a distinction made by suburban than by urban students. That is to say, in almost every case a greater percentage of suburban students indicated preference for designing solutions than did their urban counterparts.

Unfortunately, there were too many insufficient cells in the race cross-tabulation to allow a meaningful analysis of all the races that responded to the survey. Therefore, only black and white students' preferences were examined. Again, the overall response was that designing solutions was substantially more desirable (Figures 4a and 4b). The differences among the problem areas were about evenly split between black and white students.

The question of gender difference was also investigated in this study. The percentage of response to each choice in this item (finding, deciding, and designing) was plotted against all fifteen problem areas for males (Figure 5a) and for females (Figure 5b). With one exception males and females alike favored designing solutions to problems above the other two choices. That choice was significant in more problem areas for males than for females.

For the most part there was no significance to the differences between "deciding what to do" and "finding reasons." There was, however, an obvious preference for "deciding what to do" as seen in all the preceding figures. Therefore, a closer scrutiny was warranted. There were no substantive differences between community types or races between these two response choices. On the other hand there were some patterns that developed between the genders.

Figure 5c demonstrates that there was pattern of preference, though not significant, among males for "designing a solution." "Deciding what to do about a problem", on the other hand, received a higher proportion of females choosing it than males (Figure 5d). Although most of the differences were non significant the pattern was still present. Finally, "finding reasons why" something is a problem was the least selected option. And, there was no clear preference by either gender.

The 675 responses to the open-ended item provided further insight. Twenty-four of them dealt directly and explicitly with ways of learning. Almost eighty percent (n = 19) said they wanted more labs and experiments. Many other responses implied this kind of preference. Some examples included: "designing machinery," "how to reduce friction in cars," and "ways of not producing so much trash." One student wrote, "How can we effectively recycle garbage?" and several others were interested in finding cures for various diseases.

There were fourteen additional responses that specifically stated an interest in working on global problems. Another nineteen indicated a concern about the future. Many other responses regarding pollution, health, energy, waste, environmental degradation and more implied similar concerns.

## DISCUSSION

There is a place in education for learning what already exists in books and in the minds of elders but it should not be its prime focus (Dewey, 1938). Students need to "feel that they are studying something, and are not merely

executing intellectual minuets (Whitehead, 1929, p. 21)." Alfred North Whitehead (1929) proposed that the subject matter for education be "life in all its manifestations" and further that we "eradicate the fatal disconnection of subjects which kills the vitality of our modern curriculum (p. 18)."

Today, more than half a century later, we are still saying the same things. Many people believe that meaningful learning "occurs at the level of concept acquisition and conceptual change (Bransford & Vye, 1989, p. 187)." Mere memorization of information does not constitute effective learning. Memorized information is likely to remain inert though it may be relevant in new situations.

Meaningful learning may be viewed as a transition from memory to action, from factual (declarative) to procedural or use-oriented knowledge, or from "knowing what" to "knowing how". To accomplish this instruction must deliberately help students learn when to apply their knowledge by presenting many different examples. It takes a long time for understanding to develop (Bransford & Vye, 1989; Resnick, 1983; Aronson & Briggs, 1987; Albee, 1968; O'Donnell, 1984). While making the transformation from declarative to procedural knowledge students learn what is important but also when to use it. If one doesn't know when to use principles, concepts, and strategies that knowledge remains inert. Thus, it is important to learn how to apply the concepts and strategies of science.

Ideally, assignment of problems should help students learn to recognize when to apply these various strategies and concepts. Their effectiveness, however, is mediated by how the practice exercises are approached. Bransford & Vye (1989) discuss problems associated with several approaches. First, the simple problem assignment. Students often fail to use the worked out problem in the text to develop generalizable knowledge. Second, students are often given practice on isolated components of skills without learning how to orchestrate them. Third, students often use information about each chapter to guide their selection of strategies. When a chapter is unavailable to rely on they are lost. Finally, solitary practice is no guarantee of effective learning and can be damaging because students are likely to persist with wrong strategies.

When designing meaningful problem-solving experiences Bransford & Vye (1989) make three suggestions: 1) create problem-solving contexts that engage the students' everyday knowledge to help them discover and correct their misconceptions, 2) create problem-solving situations where students can learn to deal with initial "dead ends" that temporarily seem impossible to solve, and 3) invite problem-finding as well as problem-solving to create a problem-

solving environment. Resnick and Klopfer (1989, p. 10) call this a "cognitive apprenticeship." Instructional design to this end requires the use of "real tasks," "contextualized practice of tasks," and "plenty of opportunity to observe others doing the kind of work they are expected to learn to do." When actual objects, events, and real tasks are not used fidelity must be maintained. That is, there must be close correspondence between the actual and the representation (Merrill, 1983; Seddon & Ridge, 1987).

An important part of instruction is motivation. The task of the instructional designer, in this regard, is to identify the students' motives and channel them into appropriate activities (Gagne, 1985). Gagne (1985) rated achievement motivation highly. He says it goes well beyond task mastery and that the act of achieving provides motivation. He also lists four techniques to acquire and maintain achievement motivation: 1) clearly define individual goals, 2) perceive self improvement, 3) assume responsibility for one's own performance, and 4) work within a supportive social environment.

"Learning is more enjoyable when one has personal control over the goals of one's activities, the difficulty of the problems one attempts, and the pacing of one's activity (Lepper & Chabay, 1985)." The consequences of this motivation include better learning and greater on task performance. That is, when students are highly motivated they may persist longer or work more intensely for shorter periods of time (Keeler, 1983)." To promote an intrinsic interest in learning Malone (1981) suggests creating a sense of personal challenge and accomplishment, stimulate curiosity and puzzlement by focusing on incongruities and discrepancies, and encourage personal control to promote active involvement. Interestingly, the inquiry approach attempts to bring the student to understanding answers to problems and questions in a similar fashion while modeling the process of being a scientist (Reigeluth, 1983; Collins & Stevens, 1983).

## CONCLUSIONS

Middle-level students clearly perceived differences among the available response choices and stated their preferences. About half of them preferred to encounter science-related problems that require designing solutions. They said so with their responses to fourteen of the fifteen problem areas in science (Table 3) and in what they wrote in response to an open-ended request for their ideas of what would make learning interesting. This choice may not have always been statistically significant but a substantial pattern did exist. Furthermore, while a higher percentage

of male students and suburban students chose designing solutions to problems than did females and urban students, there were no differences between black and white students.

In a study of gender differences in science interests Martinez (1989) found that middle-level males were more attentive to aspects that elicit perceptions of control in experiments, and females were more attentive to the social aspects. In the present study males expressed greater preference for designing solutions than females while females expressed a greater preference for deciding what to do about a problem than males.

Preference research can inform instructional design by providing ideas for interesting and motivating problems to study in science classes. We might also learn about what instructional designs might be most compatible with various types of problems to be solved. Martinez (1989) concluded that motivational enhancement of science experiments effects subsequent choices to participate in science experiments. Furthermore, he says enhancing the interest value of experiments effects females to a greater degree than males.

Interests, preferences, and motivation may be different aspects of the same domain. Since interest and motivation are positively correlated with achievement it would seem appropriate to identify low motivation students. Then, use their preferences to inform the design of strategies that will help them develop appropriate behaviors, levels of responsibility, readiness and ability to learn.

## SUMMARY

### Introduction

This study explored how middle-level students preferred to work on science and science-related problems. It may be as important to assess students' instructional preferences as their abilities before deciding on optimal forms of education. Students' preferences may indicate the types of instruction most likely to improve or maintain academic motivation if not also give special insight into what would be generally effective instruction.

Approximately 850 middle-level students, in grades 7, 8, and 9, responded to the survey. There were only slightly more females than males. White, Black, Hispanic, Asian, and Native American students were invited to participate. They attended urban, suburban, and rural schools, 13 in all, in 9 New York State counties (table 1).

Questions on fifteen problem areas in science were distributed across five survey forms. Each student was asked questions on three of the problem areas and an open-ended question about what they would most like to work on in science class.

## Results

Students indicated their interest in the general problem areas on a five point Likert-type scale. The sum of the responses to the high and very high choices was taken as a measure of interest in each problem area. They were then ranked from highest to lowest interest.

Table 3 summarizes the student interest ratings for all fifteen problem areas. The most preferred problem areas included wildlife, water resources and natural disasters while those that were least preferred included energy conservation, human population, and solid waste.

Every problem area offered an opportunity to ask students about three "ways of learning." They were: "finding reasons why it was a problem," "deciding what to do about the problem," or "designing solutions for the problem."

By averaging the percentage of response to each way of learning across all fifteen problem areas (Figure 1) one can see that designing solutions was most highly preferred.

When the percentage of response to each of these choices was plotted against the fifteen problem areas (Figure 2) it can be seen that "designing solutions" was preferred in fourteen of them. Furthermore, ten of them were significant ($p < 0.05$) plus two more are substantially different ($p < 0.10$) from "deciding what to do."

There is a peculiar pattern seen in figure 2. More problems show significant differences at the lower end of the interest scale than at the higher end. While less intense, a similar pattern exists with the "deciding what to do" response. A strikingly similar pattern emerged from cross-tabulations by community type, race, and gender. While generally not statistically significant, further analyses showed a greater preference for "designing solutions" among suburban students and male students.

With one exception figure 5c shows that males and females alike favored "designing a solution for the problem." Males, however, made the choice at a substantially higher rate than females in about half the problem areas. For the most part there was no significance to the differences between "deciding what to do" and "finding reasons."

"Deciding what to do about a problem", on the other hand, received a higher proportion of female preference (Figure 5d). Although most of the differences between females and males were non-significant the pattern was still present. Finally, "finding reasons why" something is a problem was the least selected option by all groups for most problem areas. And, there was no clear preference by either gender.

The 675 responses to the open-ended item provided further insight. These were largely content ideas but, twenty four of them dealt directly and explicitly with ways of learning. Nineteen students (79%) said they wanted more labs and experiments. Many other responses implied this kind of preference. Some examples included: "designing machinery," "how to reduce friction in cars," and "ways of not producing so much trash." One student wrote, "How can we effectively recycle garbage?" and several others were interested in finding cures for various diseases.

There were fourteen additional responses that specifically stated an interest in working on global problems. Another nineteen indicated a concern about the future. Many other responses regarding pollution, health, energy, waste, environmental degradation and more implied similar concerns.

## Conclusions

Middle-level students clearly perceived differences among the available response choices and stated their preference. About half of them preferred to encounter science-related problems that require designing solutions. They said so with their responses to fourteen of the fifteen problem areas in science (table 3) and in what they wrote in response to an open-ended request for their ideas of what would make learning interesting. This choice may not have always been statistically significant but a substantial pattern did exist. Furthermore, a generally higher percentage of male students and suburban students chose designing solutions to problems than did their counterparts.

In this study, students' preferences for how they wanted to learn seemed to be related to their level of interest. As their interest waned it became increasingly preferable to design solutions to problems.

Preference research can inform instructional design by providing ideas for interesting and motivating problems to study in science classes. We might also learn about what instructional designs might be most compatible with various types of problems to be solved.

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TABLE 1A: DISTRIBUTION OF STUDENTS RESPONDING TO SURVEY BY GRADE AND SEX

| | | | % (n) |
|---|---|---|---|
| GRADE | | 7 | 36 (304) |
| | | 8 | 40 (340) |
| | | 9 | 24 (207) |
| | | TOTAL | 100 (851) |
| SEX | | FEMALE | 51 (432) |
| | | MALE | 49 (416) |
| | | TOTAL | 100 (848) |

TABLE 1B: DISTRIBUTION OF STUDENTS RESPONDING TO SURVEY BY RACE AND COMMUNITY TYPE

| | | % (n) | % in New York State (1987) |
|---|---|---|---|
| RACE | WHITE | 54 (442) | 62.3 (349,060) |
| | BLACK | 24 (196) | 19.6 (110,058) |
| | HISPANIC | 12 (101) | 14.0 (78,256) |
| | ASIAN | 5 (41) | 3.8 (21,300) |
| | NATIVE AM | 3 (29) | 0.3 (1,586) |
| | OTHER | 1 (9) | |
| | TOTAL | 100 (818) | 100 (560,259) |

| | | | Bldg. | Dist. | Co. |
|---|---|---|---|---|---|
| COMMUNITY | URBAN | 61 (516) | (7) | (5) | (5) |
| | SUBURBAN | 31 (267) | (5) | (3) | (3) |
| | RURAL | 8 (65) | (1) | (1) | (1) |
| | TOTAL | 100 (848) | (13) | (9) | (9) |

TABLE 2: EXAMPLE OF TYPES OF QUESTIONNAIRE ITEMS

1. Which wildlife problem would you like to work on most?

   A. wildlife management [fishing/hunting/trapping]

   B. wildlife habitat loss [importance to humans]

   C. wildlife extinction [survival needs]

   D. I am not interested in any of these choices.

2. If you did work on a wildlife problem, how would you prefer to do so?

   A. finding reasons why this is a problem.

   B. deciding what to do about the problem.

   C. designing a solution for the problem.

3. How interested are you in working on wildlife problems?

| A | B | C | D | E |
|---|---|---|---|---|
| no interest | low interest | moderate interest | high interest | very high interest |

4 Which kinds of problems would be more interesting for you to work on in science class?

   A. local problems [close to home]

   B. regional problems [our own state and its neighbors]

   C. national problems [all 50 states]

   D. world wide problems [all countries]

5. In addition to the problems I have seen on this survey, I would like to work on: _____

TABLE 3: PERCENTAGES OF STUDENTS CHOOSING HIGH OR VERY HIGH INTEREST IN GENERAL PROBLEM AREAS

| RANK | PROBLEM AREA | | % (n) |
|---|---|---|---|
| 1 | WILDLIFE | WL | 45 (71) |
| 2 | WATER RESOURCES | WR | 44 (76) |
| 3 | NATURAL DISASTERS | ND | 44 (69) |
| 4 | OUTDOOR AIR QUALITY | OA | 41 (68) |
| 5 | PERSONAL | PR | 41 (68) |
| 6 | FUTURE | FT | 39 (61) |
| 7 | INDOOR AIR QUALITY | IA | 37 (58) |
| 8 | HUMAN HEALTH (DISEASES) | HH | 34 (60) |
| 9 | LAND USE (ECOLOGY) | LU | 27 (50) |
| 10 | FOOD RESOURCES | FR | 25 (39) |
| 11 | ENERGY RESOURCES | ER | 24 (43) |
| 12 | NATURAL RESOURCES | NR | 24 (38) |
| 13 | ENERGY CONSERVATION | EC | 21 (35) |
| 14 | HUMAN POPULATION | HP | 20 (34) |
| 15 | SOLID WASTE | SW | 19 (31) |

Fig. 1: Ways of Learning

overall preference n=851

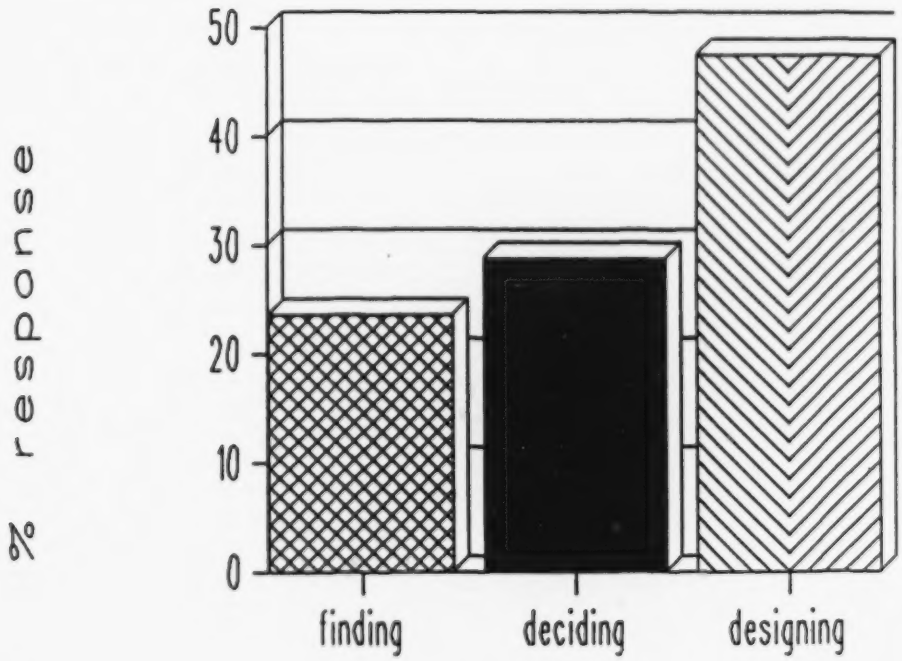
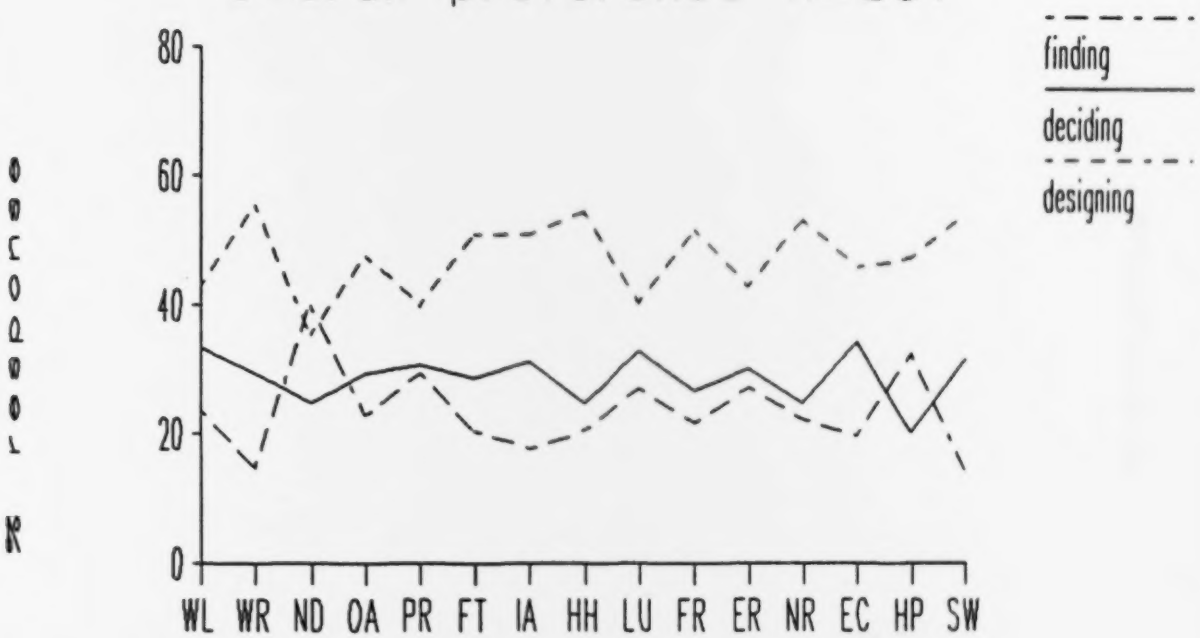


Fig. 2: Ways of Learning

overall preference n=851

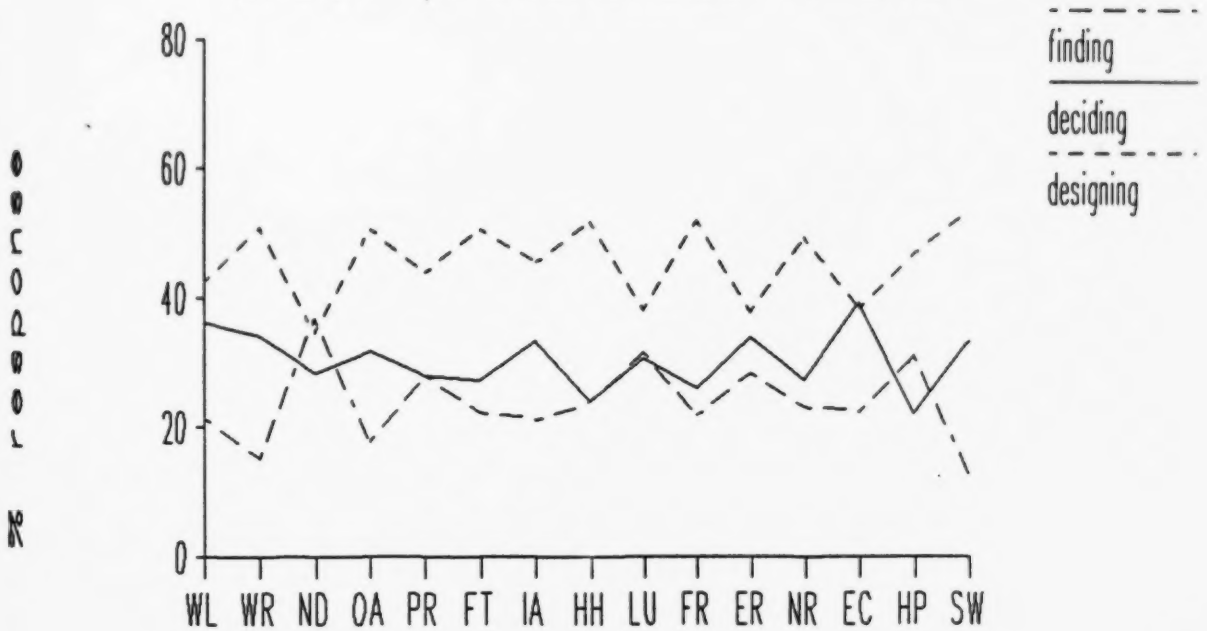



problem areas

(high to low interest)

Fig. 3a: Community

urban preferences n=516

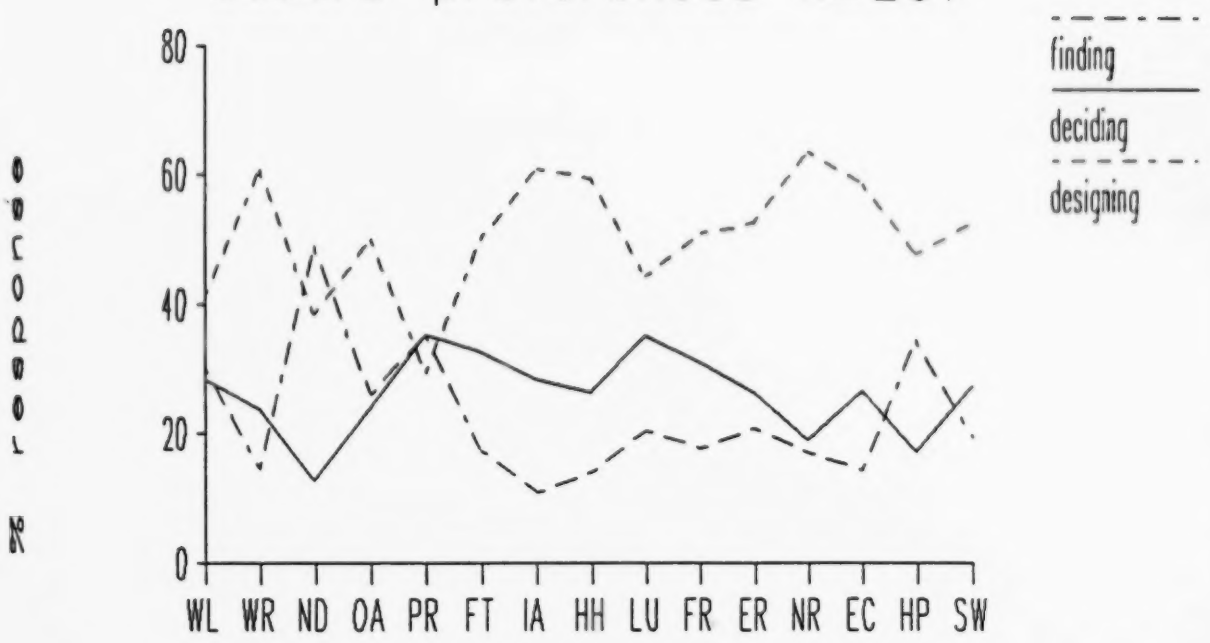



problem areas

(high to low interest)

Fig. 3b: Community

suburb preferences n=267

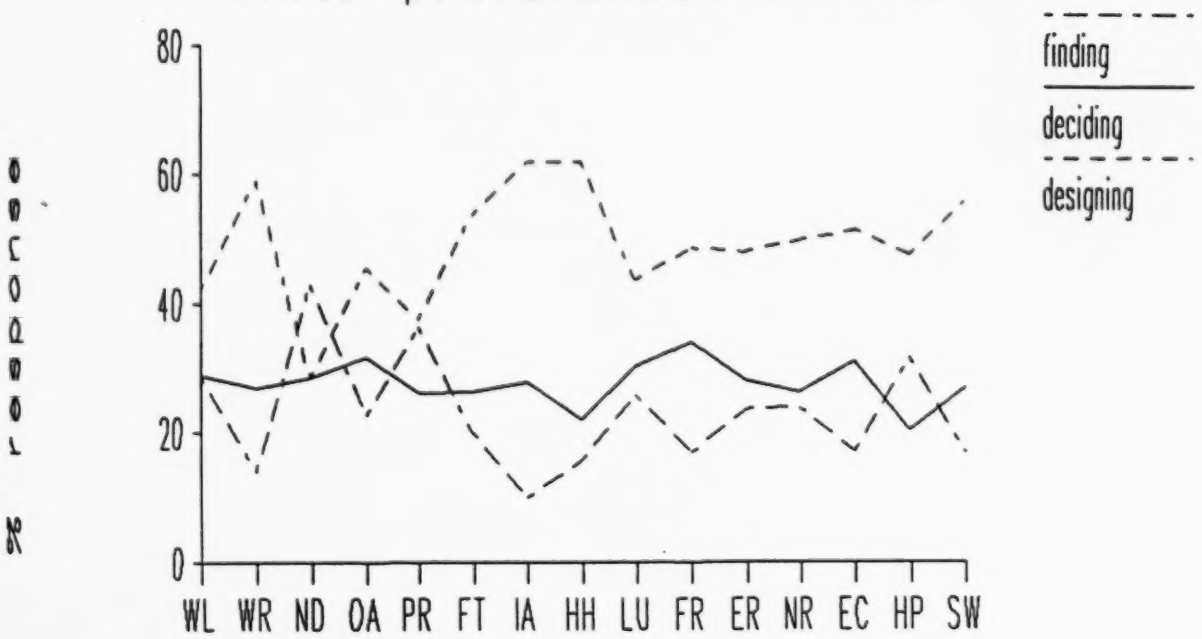



problem areas

(high to low interest)

Fig. 4a: Race

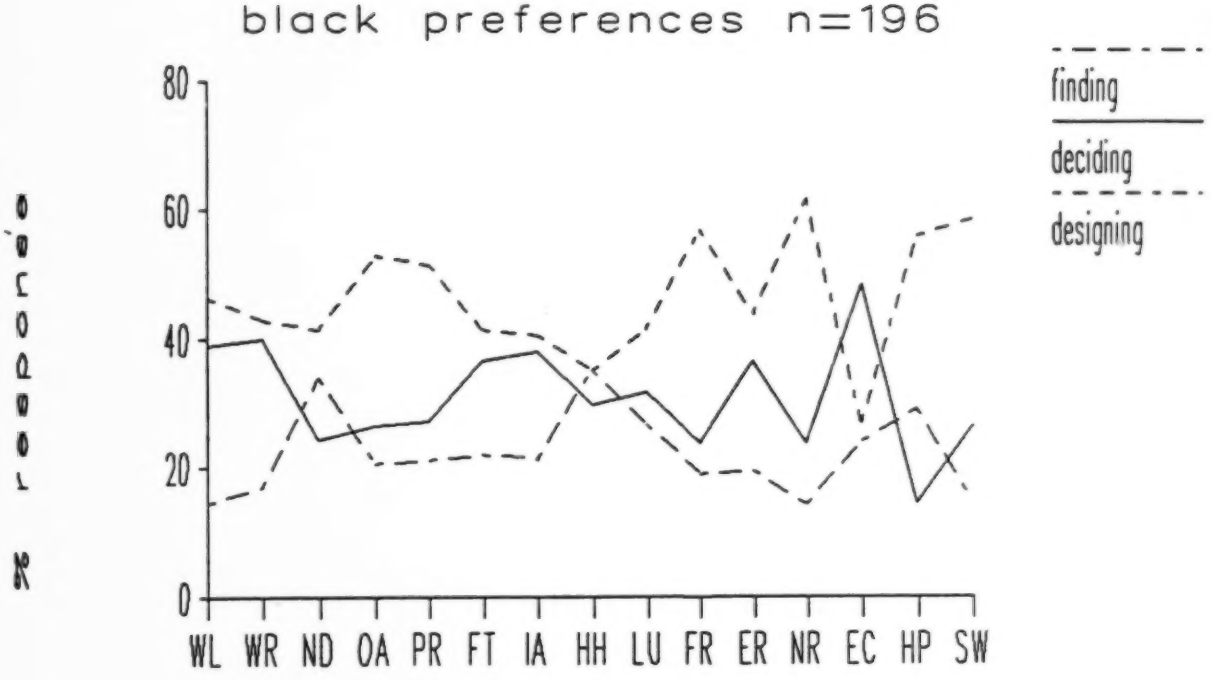
white preferences n=442




problem areas

(high to low interest)

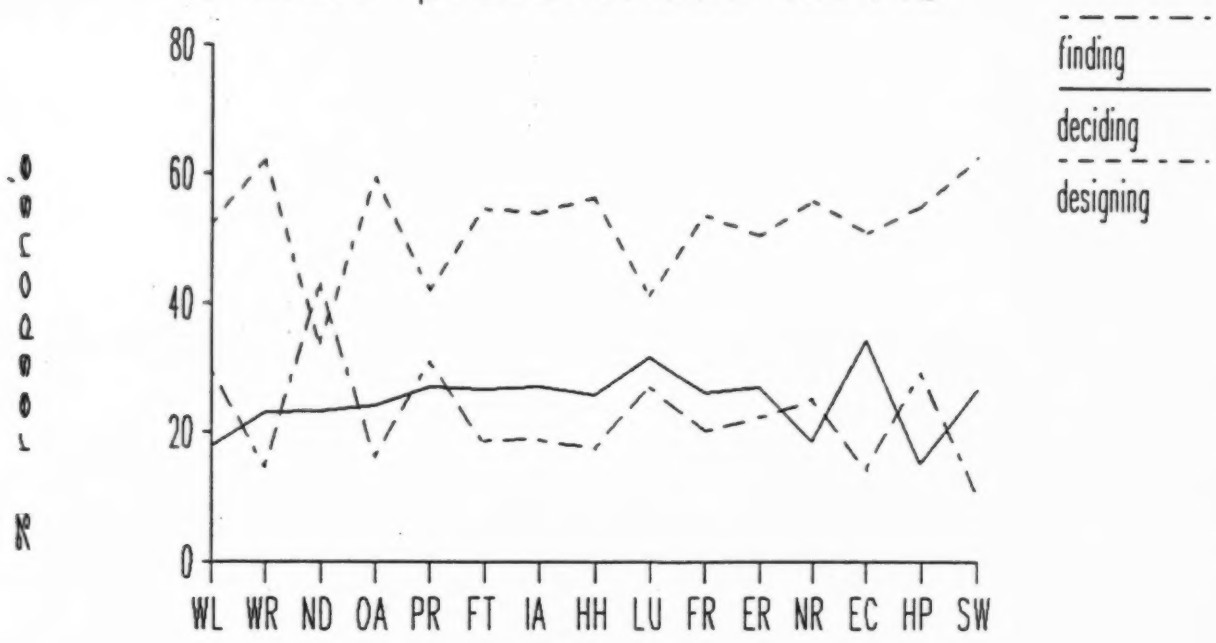
Fig. 4b: Race




problem areas
(high to low interest)

Fig. 5a: Gender

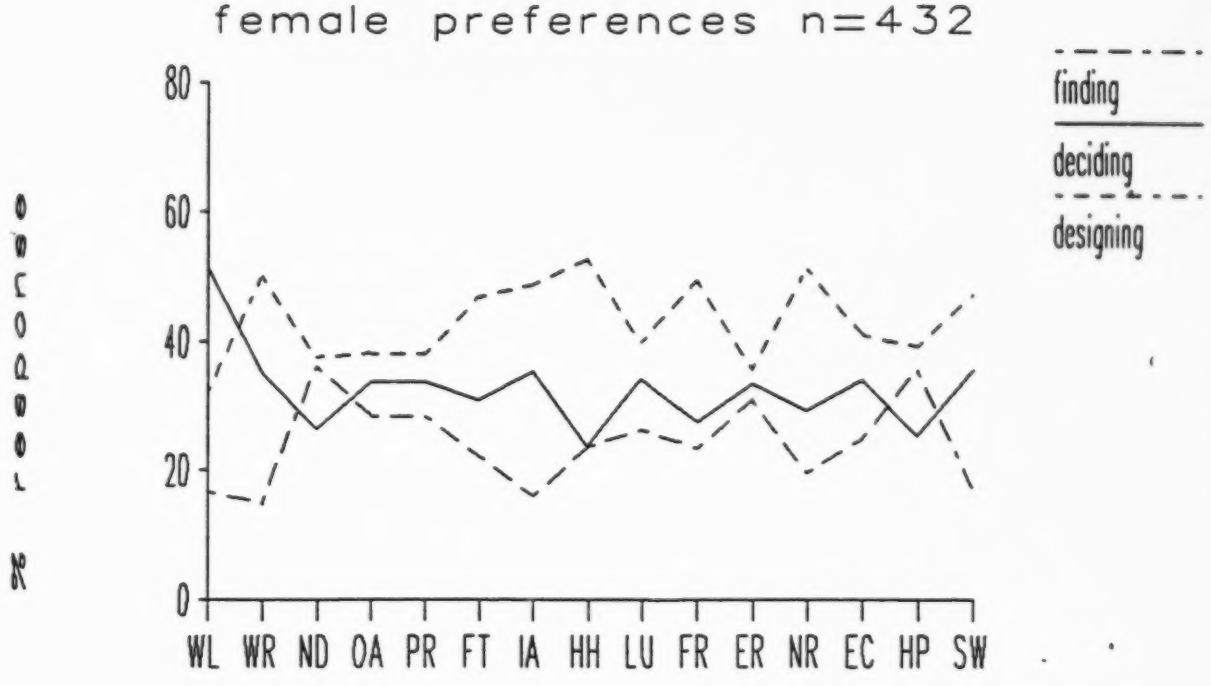
male preferences n=416




problem areas

(high to low interest)

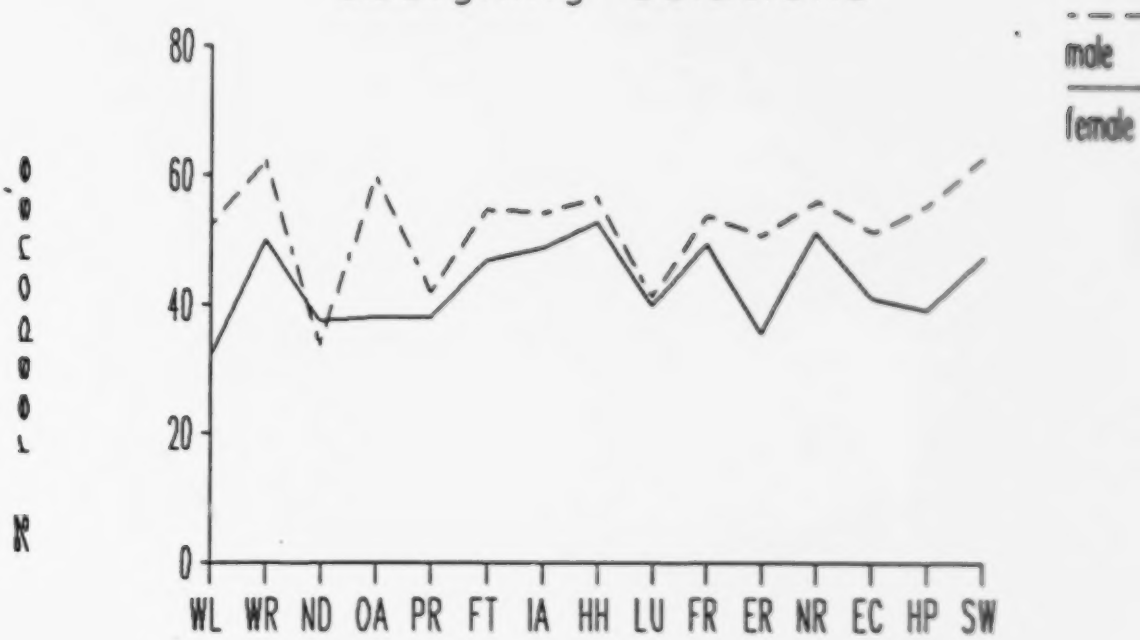
Fig. 5b: Gender




problem areas
(high to low interest)

Fig. 5c: Gender

designing solutions

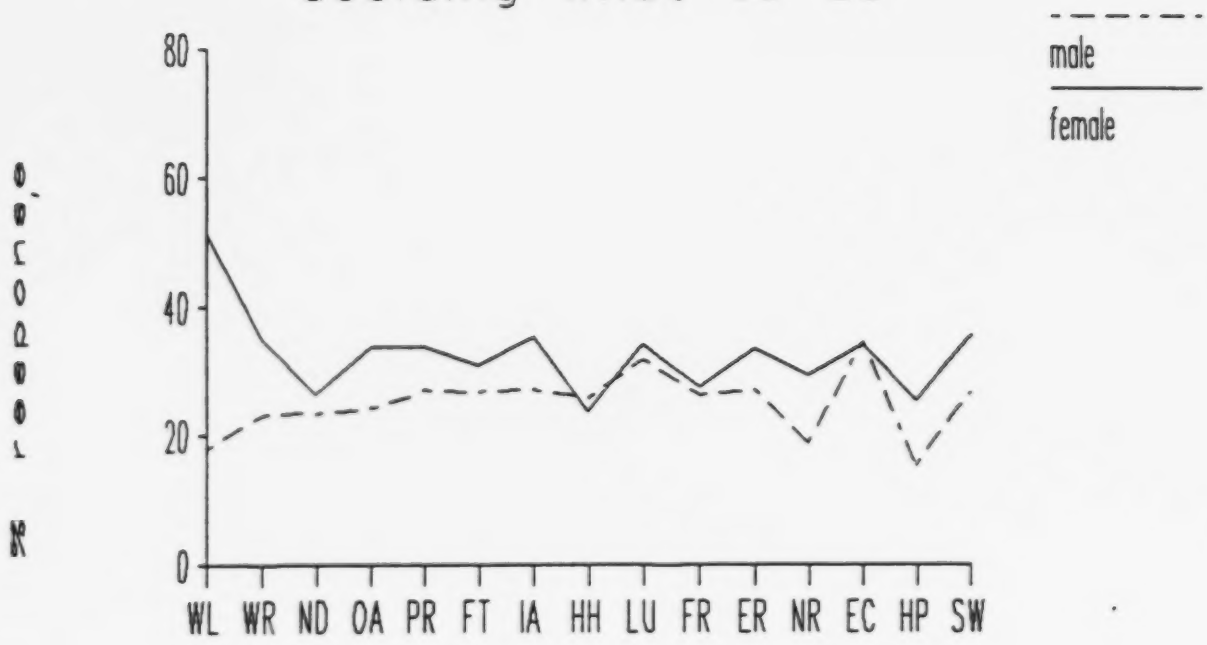



problem areas

(high to low interest)

Fig. 5d: Gender

deciding what to do




problem areas

(high to low interest)